VIRTUAL ENVIRONMENT COMPOSABLE TRAINING FOR OPERATIONAL READINESS (VECTOR)

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ABSTRACT

An immersive training system, called Virtual Environment Cultural Training for Operational Readiness Training Delivery (VECTOR-TD), was developed to provide scenario-based virtual environments to support cultural familiarization. This paper describes the cultural-training application, the architectural design, and the associated implementation of the immersive environment and intelligent agent technology to control game non-player characters (NPC). One of the innovative features of the virtual environment is the use of executable cognitive models and emotion models which play significant roles in the overall reactions and behaviors of NPCs toward the trainee. In addition to influencing the behavior of the active NPCs, the emotion models constrain interactions with NPCs encountered later in a scenario. Recent additions to the VECTOR system include a scenario authoring capability that utilizes a graphical programming paradigm to enable scenario content authoring for execution within the VECTOR training system. The significance of VECTOR-SE is twofold. First, it dramatically reduces the time and skill required to develop VECTOR scenarios. Second, VECTOR-SE makes scenario development or modification accessible to a wider audience of professionals. VECTOR-TD and SE are currently being evaluated at the U.S. Military Academy at West Point.

1. INTRODUCTION

The number of military activities classified as "operations other than war" (or OOTW) is on the increase. Often called asymmetric warfare, these activities may include counter-insurgency campaigns, hostage rescue operations, low intensity conflicts, military operations in urban terrain (MOUT), and peacekeeping operations. Such activities will require a vastly different set of tactics, equipment, training, and skills than conventional military engagements of the past. Future conflicts may not involve commitments of massive numbers of troops to fixed battle zones, but will likely involve combating small units of fanatical terrorists. Moreover, these missions will require leaders and soldiers to possess a different set of skills from what was required for success in traditional combat situations. They will typically require leaders, at all levels of command, to interact and communicate personally and effectively with people whose cultures, languages, lifestyles, and beliefs are very different from those found in the U.S.

The Virtual Environment Composable Training for Operational Readiness (VECTOR) program was developed by CHI Systems under the sponsorship of the Army Research Institute (ARI) to meet these needs. The VECTOR system couples a commercial game engine with an executable cognitive architecture to provide a highly interactive and intelligent agent controlled training environment where soldiers can learn cultural knowledge and practice interpersonal interaction skills. This paper provides a programmatic and technical summary of the VECTOR systems and an example of the technology development process within the Small Business Innovative Research (SBIR) program to meet specific Army training needs.

1. PROGRAM BACKGROUND

VECTOR was initially developed as a Phase I Small Business Innovative Research (SBIR) effort, funded by the ARI Virtual Training Environments Team, to provide a new technology for training in cultural familiarization through the application of highly experiential, scenario-based training in virtual environments that can be used to develop specific skills for interacting with members of a culture of interest (Weiland, Deaton, Barba & Santarelli, 2003). This training directly supports counter-asymmetric warfare requirements by enabling all personnel assigned to a particular region/country/operation to be better prepared to deal with decisions linked to an unfamiliar social context.

In Phase I it was determined that VECTOR training content would focus on peacekeeping operations within the cultural context of the Arabic population of Iraq. A major product of our Phase I research was the

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 NOV 2006	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Virtual Environment Composable Training For Operational Readiness (VECTOR)	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **CHI Systems, Inc Ft. Washington, PA 19034**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002075., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

development of a training scenario, suitable for implementation in a virtual environment, which demonstrated the application of cultural knowledge to enhance mission success. A number of key technology areas were considered in this development, including: 1) virtual environment/3D graphics development, 2) speech recognition and synthesis, 3) cognitive modeling, 4) intelligent tutoring/training systems, and 5) advanced interaction technologies. The concept was to employ such technologies in the design and development of synthetic actors to represent the members of the other culture.

The purpose of the Phase II effort was to expand the set of cultural principles and lessons that were developed during Phase I, and then incorporate these into an expanded training scenario (Deaton, et al., 2005). Training infrastructure also had to be developed to support representation of culture-related behavior and speech-based agent dialog. During Phase II the decision was made that the virtual environment aspect of VECTOR would be provided by a COTS game engine. After a detailed trade study, the Lithtech Jupiter game engine was selected. Initial software development work focused on the integration of the iGEN® cognitive agent framework (used for synthetic agent control) with the Jupiter game engine.

VECTOR represents a virtual training environment incorporating cognitive-model-controlled Non-Player Characters (NPCs) that facilitates the delivery of cultural-familiarization training. Through the use of a cognitive model of NPC behaviors using a cognitive architecture and a generic scenario language, cultural rules were encoded and mapped to scenario-specific NPC dialog and behaviors, thereby providing a set of virtual NPCs with which the trainee can interact. Additionally, the NPC model contains an emotion model that modulates NPC dialog and actions based on underlying trainee actions and dialog. VECTOR demonstrates the feasibility of integrating a cognitive architecture with a commercial game engine to provide immersive cultural training. The Phase II software development effort addressed basic technical challenges, culminating with a complete proof-of-concept demonstration of scenario-based cultural training. Many areas of development were experimental in nature and did not necessarily result in fully implemented functionality, but rather provided the technical infrastructure necessary for ultimate extensibility.

The results of the Phase II VECTOR development identified scenario content generation as a major obstacle to the development of game-based training systems both in terms of cost and development time. Although the VECTOR system was successfully developed, it contained limited training scenario content at the end of the Phase II effort. This was due to the difficulty of encoding training content in a form that is executable within both the game engine and cognitive architecture. It was determined by ARI's Research and Advanced Concepts Office that the VECTOR architecture should be extended to include authoring capabilities to enable non-programmers to create variants of the existing VECTOR scenario and to create completely new scenarios. This new Scenario Editor systems component is referred to as VECTOR-SE. Provision of authoring capabilities has two major advantages: 1) It allows for systematic and repeatable manipulation within the existing scenario in order to support experimentation within this virtual environment; and 2) It provides the ability to add content to this generic interpersonal skill training system capitalizing on the Army's initial investment. VECTOR-SE is based on an instructional design process model and involves the specification of learning objectives, the creation of scenario segments (i.e., vignettes), the authoring of character/trainee dialog, the designation of dialog branching, the placement of characters at game locations, and the designation of when training assistance/remediation will be delivered.

The significance of VECTOR-SE is twofold. First, it drastically reduces the time and programming skill required to develop game-based scenarios. Within the original VECTOR project, a 15-minute cultural training scenario was developed which required 2 months of programming and cognitive modeling effort. The same scenario was later implemented in VECTOR-SE in under 3 days. Additional scenarios with comparable complexity have also been implemented using VECTOR-SE and similar significant reductions in development time have been observed. Second, VECTOR-SE makes scenario development or modification accessible to a wider audience of professionals. Work on the VECTOR program is continuing for ARI and is addressing both scenario authoring and synthetic instructor feedback enhancements (see Barba et al., 2006).

3. THE NEED FOR CULTURAL TRAINING

Conducting OOTW frequently requires tact and an understanding of the motives and tendencies of indigenous populations in order to defuse tense situations peacefully, prevent civil disturbances from becoming violent, and obtain the cooperation of the population. The goal of VECTOR is to provide trainees with the opportunity to explore the breadth of cultural behaviors related to a specific cultural group and to observe the effect of cultural behaviors (appropriate and inappropriate) within the context of a realistic military situation. The cultural focus is presently on the Arabic culture.

The development of the immersive environment is premised on the idea that conventional forces will increasingly be required to undertake missions, such as peacekeeping, where cross-cultural interactions play a significant role in determining success or failure. These conventional forces will not have the benefit of intensive real-world experience, which is common in Special Forces, and may in fact need to be deployed with limited forewarning. VECTOR is intended to deliver a brief, intensive, effective, and rapidly-adapted training program in cultural interaction that will benefit conventional forces subject to time constraints and training needs on a large scale.

Specific training scenarios are designed to make trainees more culturally sensitive, in general, rather than to instill in them specific rules of behavior in particular contexts. If a trainee comes away from the training with a list of rules (i.e., dos and don'ts) for a particular cultural situation, this would be valuable. But an even more valuable outcome of the training would be if that trainee were to begin to develop, or just become aware of the need for, adaptive strategies for dealing with difficult/ambiguous cultural contexts.

The development of VECTOR is premised on the idea that learning cultural knowledge requires more than merely inculcating a set of behavioral rules in trainees. In some sense, trainees need to internalize a mindset. Of course, a specific set of cultural encounters in a training scenario will never serve to cover all possible cases that a soldier may encounter in real life. It follows that the scenario needs to be designed to generalize into a broader understanding of cultural issues. In this sense, the training approach used in the simulation is consistent with constructivist, case-based learning which encourages the exposure of trainees to a broad base of experience, in a compelling and memorable environment (see Riesbeck, 1996 for a discussion of this approach).

The essential lesson for trainees to learn from the virtual environment is that cultural situations – whether in Kurdistan, China, the Philippines, etc. – inevitably call for interpretations and conduct that diverge from their normal, taken-for-granted ways of acting or processing social cues. To accomplish this training goal, the scenario requires trainees to recognize that a particular situation calls for cultural sensitivity and then use their general knowledge of the culture to assess the most appropriate course of action. Remembering the correct "cultural rule" for the situation is important, but only to the extent that it helps trainees tap into and develop higher-level reasoning skills which will serve them well regardless of the specific cultural context.

To construct a realistic immersive environment, the VECTOR team gathered a large data set consisting of Arabic, as well as Kurd-specific, cultural information, as it applies to peace-keeping type missions. This information was synthesized from multiple sources, including books (e.g., Izady, 1992; Kreyenbroek & Allison, 1996), articles (e.g., Ruff, 1998), and military technical reports and pamphlets (e.g., Wise et al., 1998). Some of the major cultural dimensions that U.S. forces would be required to understand in Iraq, as well as many other cultures, including: gender, religion, status, perceptions of/attitudes toward American culture/individuals, interpersonal space (proxemics) and interaction, and emotion/personality tendencies or predispositions. A number of elements from each of these cultural dimensions were then integrated into several scenarios.

4. THE VECTOR SYSTEM

In order to facilitate the training delivery aspects of the VECTOR system, the decision was made to use a realistic first-person perspective 3D game environment which would both appeal to target demographic group and also be compelling enough to motivate trainees to learn. To create this virtual environment two major components were required: the Lithtech Jupiter Game Engine and iGEN® Intelligent Agents.

The Lithtech Jupiter Game Engine provides the virtual 3D world for the simulation. It has proven to be a viable game engine, as it has been used to create AAA game titles such as TRON® 2.0 and No One Lives Forever™ 2. This engine provides the ability to create a 3D world representing a sample Iraqi village in high detail, NPCs (i.e., avatars) capable of realistic interactions, and connections to the iGEN® Intelligent Agents. Intelligent Agents are used to control both the NPCs that exist in the game and any instructor entities that watch over the game. The intelligent agents provide NPCs with behaviors, emotions, and actions, depending on how the user interacts with them. Figure 1 provides the top-level architecture of the VECTOR system. The Jupiter Game Engine is a client/server engine, with the iGEN® Intelligent Agents connecting to the server via TCP/IP sockets. We also have incorporated dialog management into the game engine to control NPC interactions in terms of text-to-speech generation and the presentation of textual dialog options to the trainee.

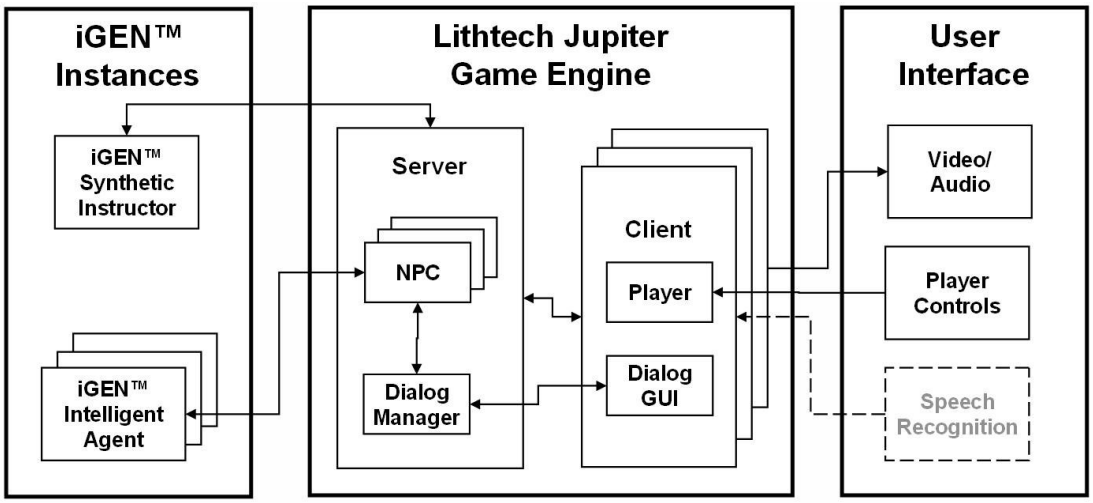

Figure 1. VECTOR top-level architecture.

VECTOR utilizes iGEN® intelligent agents to drive and control the behaviors of the NPCs, including the synthetic instructor. The NPCs control the cognitive and emotive functions of the (virtual) indigenous human population in the scenario and drive avatar actions, movements, and speech. Each cognitive agent reads in a scenario script, analogous to an actor's script, which contains NPC dialog, emotional state information, and cultural information. One of the most important aspects being modeled by the agents is that of NPC emotional states. The emotional state is used to drive and alter NPC behaviors, including dialog interactions and physical expressions. VECTOR uses the "event appraisal" models, particularly the Ortony, Clore, and Collins (1988) (OCC) model to replicate emotional states within the cognitive agents. These models treat emotional states as valenced reactions to events, objects, and agents. There exist base parameters for cultural and emotional norms for all NPCs, and the aforementioned scenario scripts are used to adjust these parameters for each NPC to give them each a unique behavior. This allows one to change an NPC's behavior by just changing its scenario script, giving the ability to create different scenarios for the trainee. An NPC's emotional state can be altered through direct interactions or through interactions with other NPCs. So a good or bad interaction with one NPC may affect a trainee's conversation with another NPC later in the game. Thus, there exists a link throughout the scenario of all of the trainee's interactions, making them accountable for all of their actions.

The synthetic instructor is a special NPC that serves to help and guide the trainee through the mission. The instructor also provides an After Action Review (AAR) at the end of the mission, telling trainees what they did right and/or wrong. In places where the trainees acted appropriately, the instructor will re-enforce why their actions were correct. In cases where the trainees made mistakes, the instructor will inform them as to what should have been done in each particular situation.

A key aspect of VECTOR is the creation of a learning environment that encourages the trainee to engage the virtual environment training. Figure 2 shows the VECTOR game-based interface and its five major components, each marked with a numbered symbol. These include a General Status Display, NPC Name Placard, Mission Objectives, Dialog Interaction Display, and a Mission Map. Each of these interface structure is explained below:

1. General Status Display: This is used to display Mission Objective (MO) information, including MO changes, additions, and completion status, as well as each instance of a cultural rule violation or adherence. Additionally, at the end of each mission, a summary of the mission is displayed with respect to a review of each cultural rule that was measured by the instructor agent.
2. NPC Placard: This shows each NPC's name, and their overall emotional state. By default, the NPC emotional state for each NPC is not displayed until initial dialog interactions.
3. Mission Objectives: This display is used to display objectives as they are issued. Each mission objective location is indicated on the Scenario Map as a blue 'X'.
4. Dialog Interactions: This display is used to present a text version of the utterances that an NPC generates (this is in parallel to the '.wav' file that is played as a companion modality to present the auditory version of the NPC utterance). Additionally, the user can 'speak' to an NPC by moving the dialog selection cursor, indicated by the '>' character and hitting return

to send the utterance to the NPC that is being spoken to.

5. Scenario Map: This displays a static 2-D overhead map of the current scenario. The user's location is displayed with a green arrow, showing location and direction of travel.

Figure 2. VECTOR display interface.

5. SCENARIO AUTHORING

Simulation-based training, despite its efficacy and potential cost savings, remains a costly enterprise due largely to the need for highly skilled (and perhaps domain-naïve) software programmers to populate training simulations with scenarios. To promote wider adoption of simulations, and to allow domain-proficient instructors to develop and edit scenarios, authoring tools are needed that enable rapid creation and modification of training scenarios for simulations. Under the sponsorship of the ARI Research and Advanced Concepts Office, a scenario editor component was successfully developed for the VECTOR system.

The authoring component was created to meet the challenge of generating training content on the scale necessary to accommodate the needs given current production methods. The bottleneck in the scenario-authoring process is not a shortage of artists or programmers but rather a shortage of training expertise (i.e., people skilled in mapping objectives to events and measures and incorporating all of that into a scenario). The authoring tool designated as VECTOR-SE assists developers with much of the mechanics of building training scenarios and imposes an approach to instructional design that helps assure that resultant scenarios will be instructionally meaningful. Research has suggested that if the scenario is linked with training objectives, then trainees are more likely to learn the training objectives (Belanich, Sibley & Orvis, 2004). VECTOR-SE substantively broadens the community of potential authors by reducing authoring difficulty (i.e., since the training expertise required to create proper scenarios is embedded within, and enforced by, the tool, more people are able to become scenario developers, achieving significant reductions in the training technology bottleneck).

In its most basic terms, VECTOR scenario authoring requires a training developer utilizing the scenario editor to generate scenario specification files. The scenario specifications can then be imported into the existing VECTOR training delivery system where they can be executed and exposed to a trainee user. The scenario authoring process was decomposed in detail to allow for the generation of functional requirements for the authoring system. The authoring system's Human Computer Interface (HCI) was then designed to implement the required functionality while adhering to the overall scenario authoring process

In the development of VECTOR-SE, we have adopted a scenario authoring process model that includes six sequential steps:

1. Scenario property specification – the process of specifying the high-level scenario information relating to why, when, and by whom the scenario was created and its intended training purpose;
2. Map selection – the designation of a preexisting map or game level where the virtual training scenario will take place;
3. Training objectives authoring – the creation of measurable training goals for the virtual training session;
4. Plot organization - the arrangement of an overall scenario to convey a complete coherent story (i.e., the plot) to the trainee;
5. Vignette editing – the process of supplying detailed data (e.g., dialog, interaction effects, character parameters) for individual plot elements; and
6. Scenario generation – the process of generating the scenario files that can be executed within the VECTOR training delivery environment.

Within each step of this process, we develop building block components of the scenario. These building blocks are threads that run through and provide necessary information at various levels of detail as the scenario is specified. The process model is embodied in the HCI design where six distinct modes have been implemented for each stage in the process. Figures 3 and 4 provide depictions of the VECTOR-SE system for both character selection and dialog authoring tasks within the Vignette editing mode. A complete discussion of the VECTOR-SE system and its functionality can be found in Barba et. al. (2006).

Figure 3. Character selection in VECTOR-SE

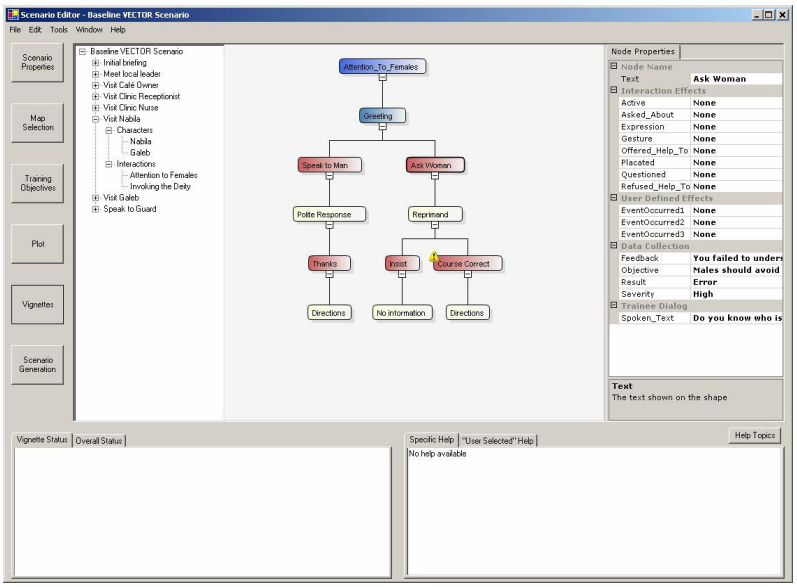

Figure 4. Dialog editing in VECTOR-SE

7. CONCLUSIONS

We have developed in VECTOR a virtual training environment incorporating cognitive-model-controlled NPCs that facilitate the delivery of cultural familiarization training. Through the use of a canonical cognitive model of NPC behaviors using the iGEN® cognitive architecture and the utilization of a generic scenario execution language, cultural rules are encoded and mapped to scenario-specific NPC dialog and behaviors and training objectives in order to provide virtual NPC's with which the VECTOR trainee can interact.

Further, recent additions to the VECTOR system to facilitate scenario authoring, termed VECTOR-SE, have been developed to provide content development and management tools that allow non-programmers to author scenarios and manipulate training parameters. VECTOR-SE is based on an instructional design process model and involves the specification of learning objectives, the creation of scenario segments (i.e., vignettes), the authoring of character/trainee dialog, the designation of dialog branching, the placement of characters at game locations, and the designation of when training assistance/remediation will be delivered.

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Work is presently continuing on the development and refinement of VECTOR-SE for ARI. VECTOR is currently being evaluation through alpha-testing at the U.S. Military Academy at West Point and arrangements have been made to utilize VECTOR to produce proof-of-concept reproductions of sample National Training Center (NTC) bilateral negations training scenario content within VECTOR using the VECTOR-SE editor.

ACKNOWLEDGEMENTS

The original VECTOR project was funded and sponsored by Dr. Bruce Knerr and Dr. Mike Singer of the U. S. Army Research Institute under the SBIR program. The subsequent development of VECTOR-SE was funded and sponsored by Dr. Jim Belanich of the U.S. Army Research Institute. Important contributions to the reported work have also been provided by CHI Systems staff members Mrs. Daphne Bogert, Mr. Larry Rosenzweig, Mr. Vance Souders and Mr. Jason Seip. All judgments and opinions presented in this paper are, however, those of the authors and do not represent positions of the U.S. Army.

REFERENCES

Barba, C. Santarelli, T., Glenn, F., Bogert, D., & Belanich, J. (2006). An approach to scenario authoring for virtual environment training. Proceedings of the 2006 BRIMS Conference. Baltimore, MD: BRIMS.

Belanich, J., Sibley, D., & Orvis, K. L. (April, 2004). Instructional characteristics and motivational features of a PC-based game (ARI Research Report 1822). U.S. Army Research Institute for the Behavioral and Social Sciences: Alexandria, VA.

Deaton, J., Barba, C., Santarelli, T., Rosenzweig, L., Souders, V., McCollum, C., Seip, J., Knerr, B., & Singer, M. (2005) Virtual environment cultural training for operational readiness (VECTOR). The Journal of Virtual Reality, 8, 156-167.

Izady, M. R. (1992). The Kurds: A concise handbook. Philadelphia, PA: Crane Russak.

Kreyenbroek, P., & Allison, C. (1996). Kurdish culture and identity. New Jersey: Zed Books.

Ortony, A., Clore, G., Collins, A. (1988). The Cognitive Structure of Emotions., Cambridge University Press.

Ortony, A., Clore, G., Collins, A. (1988). The Cognitive Structure of Emotions., Cambridge University Press.

Riesbeck, C.K. (1996). Case-based teaching and constructivism: Carpenters and tools. In B.G. Wilson (Ed.), Constructivist learning environments: Case studies in instructional design. Englewood Cliffs, NJ: Educational Technology Publishing.

Ruff, C. (1998). "Exploring Islam." Washington Post, 13 May.

Weiland, W., Deaton, J., & Barba, c. (2003). Virtual environment cultural training for operational readiness: VECTOR. (Final Report). U.S. Army Research Institute for the Behavioral and Social Sciences. Orlando, FL. CHI Technical Report 021223.02008

Wise, C., Hannaman, D., Kozumplik, P., Ellen, F., & Leaver B. (1998). ARI Contract Report 98-06: Methods to improve cultural communication skills in Special Operations forces. United States Army Research Institute for the Behavioral and Social Sciences.

Zachary, W.W., Ryder, J.M., Ross, L., & Weiland, M.Z. (1992). Intelligent computer-human interaction in real-time multi-tasking process control and monitoring systems. In M. Helander and M. Nagamachi (Eds.), Design for Manufacturability. New York: Taylor and Francis.